

orbiter images, thermal inertia and rock abundance provide clues about the properties of potential Mars landing sites.

Here we discuss the combined albedo [4], thermal inertia [2,5], and rock abundance [6] results [derived from Viking Infrared Thermal Mapper (IRTM) data collected 1976–1980] for regions that fit the Pathfinder landing constraints: areas below  $\sim 0$  km elevation between  $0^\circ$  and  $30^\circ\text{N}$  latitude. Lately there has been considerable discussion of the uncertainty in thermal inertia derived under a relatively dusty martian atmosphere [7–11]. In particular, Hayashi et al. [8] suggest that the thermal inertias, which we describe below, are 50–100 (units of  $\text{J m}^{-2} \text{s}^{-0.5} \text{K}^{-1}$ , hereafter referred to as “units”), too high for regions with moderate and high inertias ( $>300$  units) and 0–50 units high for regions of low inertia ( $<300$  units). However, our interpretation of physical properties is general and accounts for uncertainty due to modeling of suspended dust.

Thermal inertia is related to average particle size of an assumed smooth, homogeneous surface to depths of 2–10 cm [12]. Rock abundance is derived from multiwavelength observations to resolve surface materials into fine (sub-centimeter-scale) and rocky ( $\sim 10$ -cm) components, based on the fact that temperature of rocks and fines can differ by up to 60 K at night [6]. Low rock abundances generally indicate areas with dust or sand deposits, while areas of high rock abundance are commonly outflow channel deposits and/or regions deflated by wind [2,5,6].

Christensen and Moore (Fig. 11, [2]) identified four physical units that describe the general variation in surface properties on Mars. The data products used in this analysis include a  $0.5^\circ$ /bin-resolution thermal inertia map [5], a  $1^\circ$ /bin-resolution Viking-era albedo map [4], and the  $1^\circ$ /bin rock abundance map [6].

Unit 1 is defined by low thermal inertia (40–150 units), high albedo (0.26–0.40), and low rock abundance ( $<5\%$ ). Unit 1 surfaces are interpreted as being mantled by dust up to 1 m thick. Most of these surfaces are in the high-elevation Tharsis, Arabia, and Elysium regions; however, two regions lower than 0 km elevation between  $0^\circ$  and  $30^\circ\text{N}$  have similar deposits: Amazonis Planitia and Elysium Basin ( $150^\circ\text{W}$ – $210^\circ\text{W}$ ).

Unit 2 is characterized by high thermal inertia (300–850 units) and low albedo (0.1–0.2), with rock abundances high but variable. Southern Acidalia and Oxia Palus ( $0^\circ$ – $60^\circ\text{W}$ ) fit this description, and are considered to be regions of active sand transport and rocky lag deposits. Other Unit 2 surfaces include Syrtis Major (elevation  $>0$  km) and Cerberus (elevation  $<0$  km), which have lower rock abundances ( $<7\%$ ) and are probably more sandy and less rocky than Acidalia.

Unit 3 surfaces have moderate thermal inertias (150–350 units), average albedos (0.15–0.25), and moderate to low rock abundances. Parts of Western Arabia near Oxia Palus and parts of Xanthe Terra and Lunae Planum fit this description. These have been interpreted as possible surface exposures of indurated dust/soil deposits similar to the crusted materials seen a few centimeters beneath the surface at the Viking lander sites.

Unit 4 has moderate-to-high inertias (210–380 units), a relatively high albedo (0.25–0.30), and a high rock abundance ( $>7\%$ ). This unit includes the two Viking lander sites [13]. The Viking sites have elements of all the above Mars surface deposit types (dust, rocks, crust) except the low-albedo, sandy material of Unit 2 [2]. Much of Chryse Planitia and parts of Isidis Planitia and Elysium Planitia ( $210^\circ\text{W}$ – $250^\circ\text{W}$ ) can be described as possible Unit 4 surfaces.

Finally, there is some interest in landing sites in or at the mouths of outflow channels. Henry and Zimbelman [14] and Betts and Murray [15] have provided IRTM and Phobos 2 Termoskan evidence (respectively) that channel floors tend to have enhanced thermal inertias probably related, in part, to the presence of blocky material on the channel floors. Henry and Zimbelman saw a general “downstream” decrease in thermal inertia in Ares Vallis, consistent with a decrease in clast size down the channel. Surfaces at the mouths of major outflow channels, however, have enhanced rock abundances [6].

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**RATIONALE FOR A MARS PATHFINDER MISSION TO CHRYSE PLANITIA AND THE VIKING 1 LANDER.** R. A. Craddock, Center for Earth and Planetary Studies, National Air and Space Museum, Smithsonian Institution, Washington DC 20560, USA.

Presently the landing site for Mars Pathfinder will be constrained to latitudes between  $0^\circ$  and  $30^\circ\text{N}$  to facilitate communication with Earth and to allow the lander and rover solar arrays to generate the maximum possible power. The reference elevation of the site must also be below 0 km so that the descent parachute, a Viking derivative, has sufficient time to open and slow the lander to the correct terminal velocity. Although Mars has as much land surface area as the continental crust of the Earth, such engineering constraints immediately limit the number of possible landing sites to only three broad regions: Amazonis, Chryse, and Isidis Planitiae. Of these, both Chryse and Isidis Planitiae stand out as the sites offering the most information to address several broad scientific topics.

An immediate reaction to proposing Chryse Planitia as a potential landing site is, “Why go back to an area previously explored by the Viking 1 lander?” However, this question answers itself. Viking 1 landed successfully, proving that it is safe and providing us with valuable ground-truth observations of the martian surface. For example, Viking Lander 1 data have provided information useful in determining the physical properties of the martian surface materials [1]. Observations such as these have undoubtedly been incorporated into the Mars Pathfinder spacecraft and rover design, making them well equipped to successfully operate in the Chryse Planitia environment. We simply don’t know with any level of certainty what

the hazards may be in the other areas. The extensive photographic coverage of Chryse Planitia by the Viking Orbiters and Earth-based radar observations has provided 100-m-resolution topography in the vicinity of the Viking 1 lander [2]. Analysis of these data and lander photographs indicate that Chryse Planitia may be unique in that features >50 km away from the lander (such as the rims of Lexington and Yorktown Craters) are visible over the horizon [3]. This type of information could potentially aid in roving-vehicle navigation. However, the most important use of the Viking orbiter data will be in simply determining the location of the Mars Pathfinder spacecraft on the surface. These same data were useful in determining the location of the Viking 1 lander to within ~50 m [4].

A landing site should ideally include access to as many different geologic units as possible. In addition to the materials debouched into the Chryse Basin by the large martian channel complex [5], the Hesperian-age ridged plains covering much of the region [6] represent the single most important geologic unit needed for age-dating materials on Mars. Composing ~3% of the total Mars surface area [7], the ridged plains are fairly widespread in comparison to other geologic units, and, more importantly, are the Hesperian epoch referent [8]. Because the Hesperian epoch represents the interval of time immediately following the period of heavy bombardment (~3.8 Ga [9]), an absolute age determined from a ridged plain sample would allow estimates of the postheavy bombardment impact flux on Mars to be calibrated. It may then be possible to determine the absolute ages of every younger geologic unit on Mars based on crater statistics. Potential Hesperian ridged plains outcrops identified in Viking 1 lander images may represent the only known bedrock exposures on Mars. Mars Pathfinder rover analyses of these materials could provide data to support the hypothesis that these are bedrock materials, which could be crucial for future sample return missions. In addition, materials washed down from the highlands may be present in Chryse Planitia. Although the absolute ages of these materials almost certainly correspond to the period of heavy bombardment, analysis of their composition could provide some insight into the early geologic history of Mars. Also, the distribution of the materials in Chryse Planitia as determined by a long rover traverse may be indicative of the channel formation mechanism. For example, catastrophic flooding would lead to a Bouma sequence deposit in the Chryse basin [10]; in liquefaction, an accretionary lobe in the debouching area results in larger particles dropping out first with smaller particles being transported greater distances [11]. The Mars Pathfinder Meteorology Package (MET) would almost certainly augment the data obtained from the Viking Meteorology Experiment. The Viking Meteorology Experiment was capable of providing information at only one height, which is insufficient for determining the boundary layer profile in Chryse Planitia. However, because the MET will provide information from multiple heights, profiles from the Viking data may be derived.

Because of the likelihood of running water debouching into Chryse Planitia in the past, the Viking 1 landing site was considered an ideal place to look for complex organic molecules [12]. Although the Viking biological experiments did not identify the presence of organic life [13], controversy still exists as to the meaning of the Labeled-Release Experiment [14]. A landing in Chryse Planitia would make it possible to investigate the composition of the same soil samples investigated by the Viking 1 lander. Rocks seen in lander images could also be analyzed, answering questions concerning their compositional and erosional properties. Depending on the

exact Mars Pathfinder landing site and the accuracy of rover navigation, it may be possible to examine the Viking 1 lander 1 itself! *In situ* erosional analysis of Lander 1 could allow the current martian weathering rate and eolian deposition to be determined. Such information could also serve as a valuable aid in developing future martian spacecraft materials. Alternatively, it may be possible to navigate from the lander to the crater caused by the jettisoned Viking aeroshell. Ejecta from this fresh crater would represent Chryse stratigraphy to a depth of ~1 m, providing additional information on the nature of the surface materials observed by the Viking 1 lander. Although crater ejecta is frequently suggested as material that should be sampled by a spacecraft during a traverse, such stops are rarely justified. Crater ejecta, especially the outer ejecta blanket, typically has the same composition as the surrounding rock. It is the traverse up to the crater rim crest where material at depth is gradually exposed, the deepest material being exposed directly at the rim crest, typically from a depth equivalent to one-tenth the crater diameter. However, a simple examination of crater ejecta from a larger-diameter crater could potentially provide some valuable information. "Rampart" [15] or "fluidized ejecta" craters [16] have been suggested as forming from the incorporation of volatile material from depth [15] or from the interaction of the ejecta curtain with a thin atmosphere during emplacement [17]. The derived volatile content and/or sediment distribution from a rampart crater (e.g., Yorktown, 7.9 km diameter, ~45 km northwest of the Viking 1 landing site) could provide clues as to which formation mechanism is the most viable.

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**RATIONALE FOR ISIDIS PLANITIA AS A BACK-UP LANDING SITE FOR THE MARS PATHFINDER MISSION.**  
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As discussed previously [1], the present engineering constraints imposed on the Mars Pathfinder mission leave only three broad regions available for site selection: Amazonis, Chryse, and Isidis Planitiae. Because of the knowledge gained by the Viking 1 mission, Chryse Planitia would make an ideal primary landing site. The